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SCHOOL PLANT AND EQUIPMENT

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School Plant and Equipment

Reviews the literature for the period, January 1948 thru July 1950. Volume XVIII, Number 1, February 1948, covers the previous three-year period.

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FOREWORD

In the Foreword of the Review on the School Plant and Equipment published three years ago, the editor reported that research on school-plant problems was "dangerously near the vanishing point." Apparently the decision at that time to continue publication of reviews of research on the subject of school plant was favorable only because of the need for research, rather than because of the existence of such research. In the preparation of the present issue, the committee found that there is still only a limited amount of published research, but it is gratifying to observe that the accumulated research of the past three years is somewhat larger than was reported in the preceding cycle. Gradually, professional educators are getting "tooled up" for the large amount of school building in the nation which has been done and which continues to be needed. Far too little research on school plant is being produced; but research activity on the topic probably does not now lag much behind research activity on many other important educational subjects.

Unfortunately, the improved condition of research on school plant during the past triennium is only relative. There is little cause for contentment. In terms of the amount of present and of anticipated school-building construction, the supply of factual data and of proven conclusions is tragically limited. Architects, school administrators, and schoolboard members engaged in the tasks of providing schoolhousing for expanding and shifting enrolments lack many items of essential information. It is greatly to be hoped that enlarged research facilities for school-plant problems will become available.

In the absence of a more extensive body of research, many of the references summarized in this issue are reports of logical analyses of problems, of personal experiences, or of current practices. Nevertheless, in many cases, because of the experience and competence of the authors, these reports are of great value.

The chapters in the present volume of the Review do not follow the organization of material in previous issues on school plant and equipment. Since no definite pattern of organization has been established in previous issues, the committee for this issue has selected an organization consisting of relatively few chapters devoted to broad, persistent topics.

Nelson E. Viles, *Chairman*
Dan H. Cooper, *Co-chairman*
Committee on School Plant and Equipment

CHAPTER I

School-Plant Programs

WILLIAM E. ARNOLD and WILLIAM B. CASTETTER *

THE seemingly endless stream of children flowing into our schools, coupled with other factors such as rising costs, obsolescent buildings, new communities, expansion of programs and services, and inadequate methods of financing new construction, have brought into bold relief some rather formidable school-plant problems. Moreover, the military situation in the Far East, as well as attendant global economic commitments, may affect indefinitely and unfavorably the realization of an adequate school plant for our children.

Perhaps as a result of the critical shortage in school-plant facilities, public concern about the problem has increased appreciably during the period under consideration in this review. Lay committees, educators and educational groups, legislative bodies and governmental agencies, as well as radio, television, and press facilities, have constantly emphasized the importance of the school-plant problem and ways by which it may be overcome.

Data on School-Plant Status

The literature of this period treating the public school plant indicates an increasing concern over present inadequacies. Significant facts and figures on various aspects of school-plant needs were presented by Hamon (20, 21), Hecht (22), Field (15), McGraw (25), Booker (5), Hagman (18), Morphet (28), Exton (12), McLeary (26), Foster and Conrad (16), Cocking (8), Viles (43), the U. S. Office of Education (42), the NEA Research Division (30), American School Board Journal (4), School Life (38), School Management (40), School Executive (37), and the American Association of School Administrators (2). Net conclusions of these reports indicate that: (a) there will be a continued increase in school enrolments, and probably 10 million more children will be found in elementary and secondary schools in 1960 than in 1947-48; (b) a minimum expenditure of $10 billion will be needed to provide buildings for estimated increases in enrolments; (c) 15 to 20 percent of the schools of the nation are obsolescent, replacement of which will require funds in addition to those noted above; (d) the backlog of plant needs cannot be eliminated until present methods of financing capital improvement programs are improved.

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* With the assistance of Charlie B. Houser.

Federal Level

The school-plant crisis has not been without remedial proposals. At the federal level, Hamon (19) reported that 43 schoolhousing bills were introduced in the first session of the Eighty-First Congress. Analysis of these proposals (13) revealed serious limitations in suggested methods of administration, such as the circumvention of state departments of education and the U. S. Office of Education in favor of other agencies.

During the period under consideration, federal legislation enacted relative to school-building construction may be summarized briefly as follows (41):

(a) *Public Law 874:* provided assistance for current operating expenses to those school systems upon which the United States government has placed financial burdens, such as "sudden and substantial increase in school attendance as the result of Federal activities."

(b) *Public Law 815:* provided $3 million to assist the several states in inventorying existing school facilities. This act is administered by the Commissioner of Education, and designates the state educational agency to carry out purposes of the act.

(c) *Public Law 352:* authorized federal loans for advanced planning of public works. Under this program, public schools can borrow money for the preparation of drawings and specifications for school plants. Loans or advances under this act are to be repaid without interest. A sum not to exceed $100 million was authorized by Congress, no loan under which may be made unless approved by state authorities. The administrator of General Services is authorized to administer the purposes of the act.

State Level

At the state level, increased recognition of the need for more adequate state financial assistance for capital outlay was apparent. Connecticut (39) enacted a 20-year school-building aid law, which is designed to assist local school districts in financing school construction.

New approaches being made in providing state aid for capital outlay have been identified by the American Association of School Administrators (2). These include apportionment of state funds on an equalization basis, equalized matching formulas, state loan funds, accumulation of capital outlay funds from current levies in advance of construction, formation of local nonprofit corporations, and state public school-building authorities. Morphet and Lindman (27) reported that 20 states include special provision for school capital needs in their state support programs. Most states, it was noted, provide capital outlay aid in a separate fund, altho Alabama and Florida capital outlay and debt service aid is apportioned annually as an integral part of the foundation program.

Other significant state plans for capital outlay aid are now in operation in California, Washington, and New York (7). The California plan provides for building aid to needy districts on a combination loan-grant

basis. The Washington plan is based on a combined "equalization-matching" formula in which the state provides from 25 to 75 percent of the cost of approved projects, depending upon the financial ability of the district aided. In New York, central school districts having an approved building program provide an amount equal to 6 percent of the assessed valuation of the district, and the state supplies the remainder up to $450 per pupil enrolled.

In reviewing the provisions for the school plant in the 48 state school systems, the Council of State Governments' report (9) noted that there are 29 states in which all, or practically all, financial support for school-plant construction must come from local sources, chiefly from the property tax.

Local Level

Locally, many school districts were forced to "devise and adjust" in order to meet the pressing need for more classrooms. Chicago (3), Seattle (23), Tacoma (35), and Milwaukee (6) systems employed portable school units to house increased enrolments. Other stop-gap proposals included a plan by Feather (14) to cut class sizes in half by operating an all-year school with two terms of six months each. Garver (17) reported a Hobart, Indiana, experiment in low cost school construction which involved utilization of a type of steel designed for factories and warehouses. Cost of construction per cubic foot was 53 cents. Examples of local school programs, based on intensive surveys, were found in Tuscaloosa, Alabama (1), San Francisco, California (10), Moline, Illinois (24), Springfield, Ohio (32), and Harrisburg, Pennsylvania (33). The latter plan, developed by the Educational Service Bureau, University of Pennsylvania, included a plant program ranging from 10 to 20 years.

Accomplishments in school-plant programs thruout the nation have been noteworthy tho still inadequate. Most notable is the increase in functional school buildings, built around activities of the child, teacher, and community. Other trends reported by Hamon (20) include larger sites, increased storage space, provisions for plant adaptability, better seeing facilities, and one-story, open type plants.

From the evidence now available, it is apparent that hundreds of local school districts are unable to build new plants under present methods of financing capital outlay programs. Cocking (8) asserted that it is necessary for all three levels of government—federal, state, and local—to participate in assuming financial responsibility for securing adequate school buildings. Morphet (28) outlined suggestions for responsibilities to be borne by each level of government. At the federal level, this would include: (a) development of plans for assisting states and local units to determine needs, limitations, and abilities; (b) a program for helping states meet plant needs; and (c) a plan for dealing with states rather than local units. State responsibility would involve reorganization of school districts, revision of many state limitations and restrictions on

school-plant construction, inclusion of plant needs in foundation programs, and provision for more adequate consultant services. Local district responsibility would involve better planning studies of need, utilizing school-plant specialists, and an emphasis on the pay-as-you-go plan of financing capital improvements.

The foregoing suggestions parallel the conclusions and recommendations of the Cooperative Work-Conference (7) at the University of California on financing school-plant programs. These recommendations included the following points: (a) increased state assistance in financing school-plant programs; (b) comprehensive state studies of school-building needs; (c) utilization of appropriate state agencies, coordinated by the state educational agency; (d) development of appropriate state controls and standards; and (e) a continuing plant program to meet capital outlay needs over a period of years.

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CHAPTER II

Planning Procedures

RUSSELL T. GREGG and STEPHEN J. KNEZEVICH

IN THE last number of the REVIEW on this topic it was pointed out that most of the literature concerning school-plant planning was devoted to *what* should be found in a school plant and *how* it should be financed rather than to the process of planning school buildings. The same is true today. Many writers have given passing reference to the desirability of participation of individuals and groups in planning, but comparatively few have discussed the organizations and processes which would utilize such participation.

School buildings are relatively permanent objects, and accordingly they must be planned and built to accommodate adequate educational programs of the future as well as present programs. As Fowlkes (17) pointed out, a school building is the largest item of instructional equipment available to faculty and students. All possible resources should be utilized in planning such equipment. Schoolboard members, administrators, architects, teachers, pupils, community leaders, and technical consultants of various kinds can contribute to the planning. The real problem is the obtaining and correlating of all the ideas which may result in better school-plant facilities.

The Problem of School-Plant Planning

The literature revealed a great deal more emphasis on the nature of the problems to be considered in planning school buildings than on the planning process itself. Five major problems of planning were discussed by Wilson (45). These were (a) determining the nature of the educational program, (b) outlining the ideal school plant, (c) evaluating the existing school plant, (d) setting up the practical school-plant expansion program, and (e) deciding on a building schedule. In addition, Holy (24) emphasized determining the type of school organization and predicting future enrolment. Essex (16) discussed nine principles of school building design: safety, comfort and health, beauty, expansibility, flexibility, association of instructional spaces, accessibility of facilities, adequacy for community use, and economy. Problems of planning the secondary school as related to site, classrooms, library, auditoriums, gymnasiums, lunchrooms, and administrative areas were treated by Hamon (20).

The National Council on Schoolhouse Construction (27) presented an over-all treatment of the elements involved in the planning of school plants. The American Council on Education (3) published a pamphlet which gave a brief treatment of a wide range of planning problems.

Twelve principles of value to persons planning school buildings were selected from the literature and reported by Vincent (39). McFadzean (26) considered four essential factors in site planning: (a) location and accessibility, (b) size, (c) physical characteristics, and (d) utility installations. The New England School Development Council (28) indicated nine elements to be considered in the selection and development of school sites. Engelhardt (12) explained factors of importance in the formulation of site needs for large urban areas.

Planning Organization and Personnel

Six steps in school-building planning were described by Courter (9) who recommended use of the resources of the professional staff and of selected lay groups. He believed that the superintendent should (a) organize a series of committees, (b) provide them with consultants, (c) keep in touch with their deliberations, and (d) expect from them reports of their conclusions. Four patterns of organization for school-building programs were proposed by Whitehead (44) and related to sizes of school systems. Functions and duties of key personnel in the planning process also received attention. Cyr and Linn (10) pointed out some educational and community activities which could be utilized in planning a school building for a rural community. Whitehead and Featherstone (43) discussed the purposes of school-plant planning organizations, including committees and their functions. Herrick (21) believed that cooperative planning procedures should be fitted to local conditions and that their effectiveness depended on available leadership.

A very extensive study of committee organization in school-building planning was made by Seagers (35). This investigation was designed to determine and utilize some technics in securing the participation of school personnel, pupils, and parents in planning. Work of the committees was described and difficulties encountered were pointed out. A guide for community participation in planning was published by the New York State Education Department (29). A lay advisory committee was recommended and worksheet forms were included to enable the committee to gather community data and to report its conclusions.

Engelhardt (14) illustrated the kinds of information that the school administrator should furnish to the architect. The information included statements of educational policy and program, and space requirements for various types of schools. Schoolman White (41) and architect Perkins (30) also voiced the opinion that if intelligent architectural planning is to be expected the architect must be provided with clear statements of educational concepts and specific information about space requirements and relationships. The values of surveys by outside experts to promote long-range planning of school-plant facilities were explained by Reavis (32). The school survey was also recommended as an important phase of planning by Stoneman, Broady, and Brainard (37) but they encouraged local participation in the survey.

Whitehead (42) explained the functions and relationships of the educational consultant. Grace (18) discussed the contributions of the state department of education and placed emphasis on consultation and advice rather than on regulation and prescription. Methods and values of teacher participation in school-plant planning were reported by Alexander (1). Sholy (36) reported an unusual method of lay participation.

Only one study was found which was concerned with the evaluation of planning procedures employed in different school systems. This was an investigation by Johnson (25) who determined the extent to which certain planning activities were employed in the development of five junior-college buildings. He concluded that the planning procedures utilized in the five situations were not satisfactory.

Coordinating the Planning Procedures

Many agencies and individuals have an interest in, and can contribute significantly to, the planning of school plants. Coordination of the efforts of these individuals and agencies is a necessity if the best results are to be attained. Cooper (8) stated that effective school-plant planning necessitates an adequate program of city planning, a long-range plan for the development of the school plant, and satisfactory coordination between the two. The importance of cooperation among public officials, boards of education, school employees, city planning personnel, and citizens was emphasized. Holy (22) pointed out that satisfactory school-plant planning is possible only when there is well conceived city planning closely coordinated with school-plant planning. He studied 100 city plans, obtained opinions from a number of city planners, and prepared a list of types of information which boards of education should furnish to planning commissions and also a list that city planners should supply to boards of education. Holy (23) also discussed such factors as major streets, railroads, civic beauty, recreational areas, and zoning in relation to their implications for the coordination of city and school-plant planning. Three ways in which planning commissions can be of assistance to boards of education were explained by Bursch (5). Briscoe (4) reported how the personnel of the Oakland, California, school system participated in the development of a city master plan, of which the school's program is one part.

Davis (11) discussed the major duties and the relationships of the school committee, the educational consultant, and the architect. Westby (40) reported on ways of coordinating the efforts of representatives from the state department of education, faculty advisory committee, and citizen advisory committee. Engelhardt (13) presented a flow chart of school building projects in the New York City schools. The chart indicated the steps taken and the agencies involved from inception of the project to the acceptance of final plans. The nature of school-plant codes, standards, and guides, and their place in school-plant planning, were discussed by Viles (38).

There is evidence of increased attention being given to conferences and workshops in which architects, contractors, schoolboard members, superintendents of schools, and other educational workers cooperatively study the problems of school-plant planning. Examples of such conferences were those conducted at New York University (7), the University of Wisconsin (19), and the University of Washington (34).

General Studies

Several important general reports in the school-plant field were published. The 1949 yearbook of the American Association of School Administrators (2) treated the entire school-building problem. One chapter was devoted to organization and administrative procedures for school-plant planning. Two other chapters dealt with the problems of projecting the educational program and planning the school site. Caudill (6) presented a small but excellent book in which he proposed how eight important questions relating to long-range school-plant planning can be answered in individual communities. A comprehensive book concerned with both educational and architectural planning, with particular attention to the elementary school, was written by Perkins and Cocking (31). An unusually strong attitude toward cooperative planning prevails thruout the book. A book by Engelhardt, Engelhardt, and Leggett (15) concerned itself exclusively with secondary-school buildings. Criteria and standards for functional secondary-school buildings, rather than the processes of planning themselves, were emphasized.

Eight articles published in a single issue of the *School Executive* (33) presented a comprehensive overview of the school-plant planning problem. Topics treated included: (a) community participation in planning; (b) functions of the board of education, superintendent, architect, professional staff, state department, and education specialist; and (c) the job of coordinating the planning enterprise.

Summary

Many of the books and articles treating the subject of school-plant facilities have suggested the desirability of wide participation of both lay and professional personnel in the planning of these facilities. The opinion appears to have become quite widespread that such participation has value not only in terms of better planned facilities but also in increased willingness to finance the school-plant program. To date, however, there is practically no research evidence to substantiate the validity of this opinion.

The studies by Seagers (35) and Johnson (25) represent a beginning of what may become a concentrated research attack concerning the values and problems of organizations and processes for school-plant planning. Investigations are greatly needed which will provide (a) the bases for determining desirable organization for cooperative planning, (b) technics for effective participation by a wide variety of groups and individuals,

and (c) the effects of such participation in producing functional plans and financial support for school-plant facilities. Indeed, the area of school-plant planning is a fertile field for developing and evaluating organizations and procedures which may have significant implications for the whole problem of democracy in school administration.

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CHAPTER III

Space and Facility Requirements

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THE importance of space and facility requirements for elementary and secondary schools has been minimized, to some extent, in the planning phase of schoolhouse construction. This aspect of planning needs to be studied constantly in order that the optimum advantages may be derived from the educational environment of our remodeled or new school buildings. The requirements of space and facilities vary with curriculums, but there are certain features among the activities within the different types of schools which are amenable to standardization.

Due to the somewhat unspecialized nature of the work conducted within the elementary school, the treatment of the problem of interior space and facility requirements in the elementary school is quite general in this chapter. This is in contrast to the more specific nature of the information advanced in treating the specialized requirements of the secondary school. This approach to the subject of space and facility requirements for both the elementary and secondary school is in no way inconsistent inasmuch as the specialized requirements of the secondary- and elementary-school buildings are similar in many respects.

Pertinent information on the size, dimensions, and facility requirements for the various activities of the elementary and secondary school have been reviewed. The proximity of these areas has been treated so that an overview of the more recent trends in space relationships can be shown. Illustrations of functional layouts for these areas provide the application of sizes and dimensions recommended.

The Elementary School

Elementary-School Classrooms

Most school-building specialists, according to the American Association of School Administrators (1), hold that a modern elementary-school program requires 30 square feet per pupil exclusive of storage and accessory spaces, as opposed to the 18 square feet of space per pupil which was presumed sufficient in the past for the traditional school program. Square classrooms are being used on an increasing scale inasmuch as they give evidence of being the most functional type.

Where elementary education has been expanded downward to include the five-year-olds, the kindergarten room should be homelike and attractive and advantageously placed to receive the morning sunlight. The American Association of School Administrators (1) advocated that such rooms be located on the first floor and have their own exits to separate

play space. A minimum of 1000 square feet of net floor area, clear of cloak and supply space, was stipulated for 25 to 35 five-year-old children by the American Association of School Administrators (1), altho the National Council on Schoolhouse Construction (31) advocated a minimum of 1200 to 1500 square feet for a like number of five-year-olds.

Elementary-School Equipment

Normally included under this heading at the elementary level are tables, chairs, piano, record player, radio, bulletin board, and ample built-in shelving and cabinet space. In general, the National Council on Schoolhouse Construction (31) recommended movable equipment in the elementary-school classroom rather than fixed equipment. It provides for a greater variety of uses and flexibility of operation. Beard and others (5) suggested that, at least in the lower grades, a fireplace be built in each classroom. With a built-in firescreen for safety, the fireplace with the children grouped around it is reported as being the best suited area for meeting with discussion groups. Window seats in the rooms of the smaller children were also recommended by this group (5). The storage space found beneath window seats is not to be overlooked. Beard and others (5) also recommended that the library center have round tables and plenty of chairs of different sizes. In the classroom no compromise should be made in the selection of desks and seats, according to the National Council on Schoolhouse Construction (31). The contribution to posture and comfort made by carefully chosen desks and seats should not be treated lightly. A sink as standard equipment in each classroom was advocated by the National Council on Schoolhouse Construction (31) which also suggested that a separate work sink be provided in each room. Durable work benches or counters were recommended for each classroom by the same authorities, with provision for tool cabinets, scrap drawers, hardware bins, and space for unfinished projects.

Sixteen to 20 linear feet of tackboard placed at the eye level of pupils using the classroom was indicated as being adequate by the American Association of School Administrators (1). Light colored chalkboards were recommended by the National Council on Schoolhouse Construction (31) in lieu of blackboards. The lighter colored chalkboards meet current demands for good light reflection and avoidance of dark areas in the classrooms. Sixteen to 20 linear feet of chalkboard was considered adequate for the average elementary classroom by the National Council on Schoolhouse Construction (31).

Individual toilet facilities were envisaged by the American Association of School Administrators (1) as being desirable for each classroom all the way thru the sixth grade with the gang toilet being relegated to the past. Beard and others (5) stated that the sight and sound of archaic installations frighten children whereas the family type fixture facilitates control.

Other Elementary-School Facilities

The multipurpose room is one which must be planned with considerable forethought. Special consideration is necessary, according to the National Council on Schoolhouse Construction (31) if such a room is to serve its purpose satisfactorily. The space to be devoted to this particular room is a function of the size of the particular elementary school and the amount of activity anticipated to be scheduled therein. The National Council on Schoolhouse Construction (31) also commented on the advisability of providing the multipurpose room with an outside entrance which would facilitate its use as an independent unit of the school. If extensive use by the community is anticipated, toilet facilities, heating, ventilating, and lighting should be zoned for this area alone.

Space for plant growing and pet keeping is recommended by Beard (5) as is the inclusion of a doll corner for the younger children in their classrooms in the elementary school. The National Council on Schoolhouse Construction (31) reminded its readers that cloakroom facilities need not be separate units except for the kindergarten group. Gang locks for the large wardrobes were recommended (31).

The problem of acoustics is best solved during the planning stage for a building, altho corrective measures may be taken to ameliorate any acoustical shortcomings in the elementary school. If but little consideration can be given the matter of acoustics because of budget limitations or other reasons, the Committee of the Staff of the 16th District Public Schools, Elmont, New York (5), recommended that provision at least be made to have the ceilings and walls of the elementary school absorb as much sound as possible.

Facilities for handicapped children must not be overlooked in planning the elementary school. The visually handicapped child, the pupil with defective hearing, those in need of speech correction, those for whom orthopedic care is prescribed, and the cardiacs require special attention in planning space and facilities. The National Council on Schoolhouse Construction (31) recommended quiet game rooms, reserved play space, special lunch service, and facilities for rest as well as adequate professional care for the handicapped child in the elementary school.

The Secondary School

Art

The American Association of School Administrators (1) indicated that work centers should be set up within the art room such as a clay center, wood center, metal center, and weaving center; and that approximately 30 to 35 square feet of floor space per pupil, exclusive of storage, is needed. The National Council on Schoolhouse Construction (31) supported this opinion and further pointed out that where possible it would be well to locate the art department convenient to the homemaking and

general shop units and to provide north light. The combination of north light and artificial illumination should always produce a minimum of 25 to 30 foot-candles on the task surface according to Roessner (36). Special art rooms may be two to three times as large in floor areas as regular classrooms, and the furniture in art rooms must be portable, according to Hanson (18). Some good illustrations and floor plans were given by Ferris (14) which showed the space relationships among all departments as well as the recommended laboratory-type art rooms.

Business Education

Shipley (38) stressed the vital need for flexibility, and the layouts he gave illustrated this important feature. This need was particularly significant in planning a one-room business department according to De Lancey (11), who also gave data on size of room, ventilation, closet space needed, and necessary equipment. Where possible, in the opinion of Freeman (16), the typing and secretarial laboratory should be 27 square feet per pupil; the bookkeeping laboratory, 30 square feet per pupil; and the office practice laboratory, 35 to 40 square feet per pupil. The *Business Teacher* (8) gave a description of a large commercial high school located in the heart of the city of New York, and by means of pictures illustrated the rooms and facilities, and outlined the program offered. Clift (9) recommended a layout for the commercial department and stressed its strategic functional location in relation to the total school plant in showing the floor plans of a new high school in Atlanta, Georgia. The commercial facilities outside the department, as such, are extremely important, according to Hypps (24), and she stressed the utilization of the whole school plant as a laboratory for the commercial department.

General Classrooms

Bursch, Gibson, and Wright (7) pointed out the transition from the old to the new type of classroom, indicating the newer phases of size and equipment. They further indicated that because of the trend toward a learning laboratory, there is need for more floor area per student which in turn leads to the need for nonstructural partitions to facilitate the ease of contracting and expanding room sizes. Van Nuys (43) showed an excellent diagram of classroom construction using demountable partitions which are fire-resistant and sound-proof. To further the flexibility he pointed out that the classroom should use four-foot portable storage units and four-foot portable bookcase units. Some of the major items to be provided for in the modern classroom according to Ittner (25) were (a) acoustically treated ceilings, (b) the proper number of either semi-indirect incandescent or fluorescent fixtures to provide 25 to 30 foot-candles at the task surface, (c) a public address and radio system with controls centered in the administrative group with outlets in each educational unit, (d) provision for present or future television reception, (e) special provisions for audio-visual education, (f) sufficient utility

outlets for projection machines and maintenance work, and (g) a heating system that can be thermostatically controlled in each classroom. Newman (33) opposed the theory of acoustically treated ceilings by indicating that treatment of the entire ceiling makes a room overly "dead" and results in increased difficulty for a teacher to speak easily. He went on to point out that: (a) it is important that most of the absorptive treatment applied in a room be on the upper wall area rather than on the ceiling, (b) treatment can extend from the top of the chalkboards to the ceiling which will give much better control of sound than the ceiling treatment, (c) there should be some treatment on each of the three sets of opposite enclosing surfaces, and (d) that it is highly desirable that walls, ceiling, and floor be nonparallel even to only a slight degree which helps eliminate faulty sound distribution and flutter echoes. Progress in this direction can be obtained by tilting the blackboards slightly which also makes for easier writing. In the opinion of Engelhardt, Engelhardt, and Leggett (13) the size, general layout, furniture, and other facilities must be related to the functional demands of the curriculum itself. These authors went on to list definite specifications for chalkboards, chalk and eraser troughs, chart cases, sunboards, shades and curtains, display boards, projection facilities, storage, and equipment. One of the first truly modern secondary schools is the Acalanes High School in Lafayette, California, where, according to the *Architectural Forum* (3), the rooms can be enlarged or decreased in size in 30 minutes by shifting partitions without upsetting the lighting, heating, or wiring in any way. This particular source also stated that the teachers and students expressed a definite feeling of "freedom and lack of inhibition" in this type of structure, and the general teacher attitude can be summed up in the phrase "simplicity is beauty." The City High School in Wayne County, Michigan, described in the *Architectural Forum* (4), is another new school which is quite different architecturally from the Acalanes High School. The American Association of School Administrators (1) concurred in most of the items mentioned above, and further indicated that rooms should be designed and equipped to reflect their use and that it is sometimes desirable to plan departmental rooms *en suite*, including a conference room and special materials library. In small high schools with considerable variation in class size, space utilization can be increased by providing classrooms of different sizes.

Homemaking

According to the American Association of School Administrators (1) all homemaking departments, regardless of size, should have facilities for teaching: (a) selection and purchase of goods and services for the home, (b) maintenance of satisfactory personal and family relationships, (c) selection, preparation, serving, conservation, and storage of food for the family, (d) selection, care, renovation, and construction of clothing, (e) care and guidance of children, (f) selection and care of the house and its furnishings and furniture arrangement, (g) selection, use, and con-

servation of home equipment, (h) maintenance of health and home safety, (i) home care of the sick and first aid, and (j) consumer responsibility and relationships. The National Council on Schoolhouse Construction (31) listed 11 specific work centers and pointed out that there should be a minimum of 30 square feet of net space per student. Some excellent layouts for such work centers were given by Lee (26). Wilkes (46) showed a very good floor plan from the Morningside High School. In selecting equipment for a department the following criteria should be used, according to Wagner (44): (a) equipment should be within the price ranges that students could buy for their homes, (b) equipment should offer students the opportunity to learn the best features of a variety of models, materials, and makes of each item that is given space, and (c) standard and de luxe models should be represented in order that students may be made conscious of the price span.

Industrial Arts

Many of our shops which were built in the 1930's were not originally planned as shops. Quite often any available space was made into the shop. McDermott (28) indicated that the industrial arts laboratory should be designed around the objectives of the program. The choice of media and the methods should be determined by the number of teachers, the appropriate divisions, the number of students, etc. The design of the shops should be functional. Floors, ceilings, and walls, service facilities, and display areas were discussed. Hippaka (21) gave some excellent principles which should be followed in planning a shop. Topics considered were objectives, cooperative planning, site selection, shop units, the individual shop, safety, and color dynamics. He also showed how the shop teacher and the architect should cooperate. Newkirk and Klingensmith (32) listed several items to be considered in planning the shop. The well-planned shop has ventilation, light placement, acoustical treatment, and color dynamics. The size of the shop was stipulated and the number of square feet of floor space per pupil station in each type of shop was specified. Wilber (45) gave some excellent suggestions and precautions which should be considered in planning the shop and gave the details of planning such area. Finsterbach (15) gave specifications for an ideal general shop and discussed the location of facilities and some of the architectural details. Floors, walls, fenestration, ventilation, and color were discussed. Willoughby (47) showed some practical shop layouts for areas and work stations. Van Duzee, Radtke, Barocci, and others (42) gave layouts which show what can be done in various areas. Bollinger (6) had many excellent suggestions for planning industrial arts facilities. He maintained this planning must start with the teacher because this is his job, and he is the expert.

Multipurpose Rooms

Lemmons (27) described a combination gymnasium-cafeteria-auditorium made from Quonset huts at a cost of $6.30 per square foot at the Randolph High School in La Grange, Texas. According to Engelhardt, Engelhardt, and Leggett (13) combinations of auditoriums and gymnasiums, tho economical, are not particularly functional because of the difficulty of combining the purposes of each. These authors pointed out that characteristics which make a gymnasium cannot be made to harmonize with the needs of an auditorium. For example, portable chairs constitute a definite fire and panic hazard. A combination gymnasium, small club room, study hall, and library which was built at the Windsor, Colorado, High School was described and illustrated in the *American School Board Journal* (2). Cochran (10) described a situation in Barrington, Illinois, where black-out drapes at the windows and projector equipment convert the cafeteria into a visual-aid room, and where the faculty dining room becomes a recording laboratory, speech corrective room, or music room by installing acoustical tile, floor-length drapes, and electronic equipment. According to Herrick (19), Cincinnati, Ohio, has designed an elementary community room. This might also serve many functions of the secondary school. Folding doors divide this particular room, providing a smaller section equipped with tables and chairs, a kitchenette unit, and files for the Parent-Teacher Association, while the larger part is used for community group meetings, faculty meetings, a small library, and a teachers' workroom. Huggard (22) described an experiment made in Seattle, Washington, combining auditorium, playroom, gymnasium, and cafeteria into one unit. According to Roessner (35) it is desirable to have any highly-developed multipurpose room near the center of the school plant.

Music

One of the most important points brought out in the literature covered indicated that the music room should be located in close proximity to the auditorium. Higgins (20) gave a very good layout for a music department for a school of 800 students and clearly indicated the space relationship that should exist between units within the department. He stated that 4000 square feet should be allocated to a music department in a school of this size. Engelhardt, Engelhardt, and Leggett (13) presented plans for a choral room, a theory room, and practice rooms. Perkins and Cocking (34) showed plans for a rehearsal room as the core of this department. A high ceiling of from 12 to 15 feet was recommended. Small practice rooms should be 8 feet by 10 feet or 10 feet by 12 feet. The American Association of School Administrators (1) discussed the desirability of having the music room near the auditorium and discussed the size of steps for a rehearsal room. The minimum width of the steps should be 48 inches, and 36 inches of lateral space should be allowed for each seating. Sixty to 80 square feet for practice rooms was recommended.

The National Council on Schoolhouse Construction (31) concurred with the ideas stated above in regard to the location of the music room, size of rooms, storage space, and practice rooms. There seems to be little disagreement as to the space and facility requirements for the music department.

Physical Education

Huggard (23) discussed the planning of the Overlake High School in Bellvue, Washington. Ultimately, the plans considered the needs of 1600 pupils. The plant was to be partially constructed for 400 pupils; expanded for 800; and again for 1600. The auditorium and gymnasium were planned separately. The fact that the gymnasium would be constructed first and used as a combination auditorium-gymnasium was considered a poor feature. The gymnasium seats 4000 when used as an auditorium and accommodates over 2000 spectators for basketball. Griffin (17) showed an unusual floor plan for a new gymnasium with an adjoining band room in Teutopolis, Illinois. Woodruff (48) gave a concise but complete report on material fixtures, and equipment recommendations for an orthopedic unit, which includes layout, dimensions, and space requirements. Monnier (29) presented a floor plan and picture of the Orchard Park High School, New York. He discussed a gymnasium which includes offices, boys' and girls' locker rooms, boys' team room, trainers' room, storage rooms, corrective exercise room, and folding doors to divide the main playing area. Glass brick was used to provide natural light. Sleeper (39) gave reasons why the new gymnasiums will tend to be larger. He told how to plan space utilization and gave rules to use in estimating needed seating capacity. He also pointed out the need for more teaching stations and showed how to attain them in the construction of the building. Murray (30) said that equipment rooms should be definitely planned, rather than using left-over space or damp dark corners. Seaton (37) discussed the safety features which should be incorporated into the construction of a gymnasium or a field house. Items such as the space around courts, walls, acoustical treatments, stairs and ramps, bleachers, storage space, and service rooms were included.

Science

Engelhardt (12) indicated that science facilities have shown a trend in recent years toward greater concentration upon general science equipment. The National Council on Schoolhouse Construction (31) pointed out that the science rooms must make provision for lecture facilities, demonstration, recitation, experimentation, and audio-visual teaching aids. Types of facilities being used are (a) separate rooms for lecture, demonstration, laboratory work, and experimentation, (b) a laboratory with one section equipped for experimentation by students and the other section of the same room equipped with seats and a demonstration desk for recitation, lecture, and teacher demonstration, (c) a laboratory equipped

with science tables facing one way so the entire room may be used for all activities, and (d) a flexible laboratory with fixed science tables, except the demonstration table, arranged around the walls. The demonstration table and pupil desk chairs should be located near the front of the room and movable work tables should be near the rear of the room. Perkins and Cocking (34) said that the general science laboratory challenges design ingenuity. They gave a minimum space requirement of 35 square feet per pupil, and indicated that altho flexibility is required in a good science department, it is hard to achieve. Engelhardt, Engelhardt, and Leggett (13) also emphasized flexibility. A greenhouse for plant life was recommended for botany. Separate lecture or demonstration rooms or separate preparation rooms are not too desirable because of the low utilization of space. The American Association of School Administrators (1) advocated that plans for rooms and equipment should be based on careful plans for the science program. They listed three general types of science facilities: (a) one room for lecture and demonstration and another room for laboratory work and experimentation, (b) a laboratory with one section for student experiments and one for teacher demonstration, and (c) a laboratory with a demonstration desk and pupil science tables which are used for recitation, demonstration, or experiment. Stoneman, Broady, and Brainard (41) gave minimum space requirements for science rooms. They listed equipment and facilities, and discussed storage spaces.

Cooperation with Architects

Two ways to indicate space requirements were discussed by Smith (40): one was by area or dimension, and the other was by the function and capacity. It may be seen that the architect has greater freedom with the second method. Pupil capacity or simply the number of student stations to plan for allows greater possibilities. Smith (40) also said that the schoolman should help the architect in correlating spaces, and in grouping departments or cooperating areas. The proximity of certain rooms and facilities may be "mandatory," "desirable," or "optional."

The functions and the objectives should be stated. Close cooperation between the teacher and the architect should produce the best results. Both are experts, but in different phases of the planning program.

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CHAPTER IV

Trend in Materials and Design

ARCHIE L. GRAY and JERALD BLAKE

RECENT trends in materials and design in school construction are the reflection of the changing needs of education. The many problems which arise in planning a functional, economical school building, varied in its uses to the community, call for cooperation among boards of education, architects, school staffs, and communities in the evaluation of these trends.

Because of the recent increase in the birthrate many classrooms are needed to provide space for rapidly increasing enrolments in the elementary schools. Enrolments in the secondary schools will show a similar increase in a few years. There is also the long-range need to design school buildings that will be flexible in their purpose if enrolments decrease or change. Unpredictable shifts in population continue to have a very great effect upon school-building needs. The schools must be designed to meet these changing needs.

School and College Management (32) reported the recent convention of the Association of School Business Officials at which Kenneth Stowell stated the main points to remember in school construction. They included (a) simplicity of design, (b) elimination of unnecessary items, (c) integration of design and materials for the sake of economy and suitability, (d) standardization of the elements of the plan to prevent waste, (e) factory fabrication to reduce time and cost, and (f) new materials and methods of construction to meet community needs efficiently.

Regardless of how much school administrators may feel the need to save money on building construction, they are obligated to design and maintain buildings that are structurally safe (27). The use of materials that are fire-resistant is imperative (41). The schools should also provide protection for the health of the pupils and the teachers by the installation of adequate service systems such as lighting and sanitation.

The rapid trend toward the one-story school is due largely to its integration of good design with safe construction and functional use. This type of construction provides less danger from such hazards as fire, tornado, and earthquake. Expensive foundations, fire proofing, and panic escape requirements for multi-story schools would seem to offset advantages gained in other ways.

Since World War II, school-building construction has been handicapped considerably by shortages of materials. Rice (31) stated that the National Conference for Mobilization of Education has asked the National Production Authority to set mandatory priorities on certain necessary school-building materials. It is hoped that this conference, composed of representatives of 83 groups interested in our nation's schools, will be able to

convince the government that priorities for school-building materials should be second only to defense materials.

There is a growing tendency to use modular construction in school buildings. When the dimensional coordination of building materials develops further, the cost of erecting schools will be reduced, because of the decreased need for on-site labor. In the field of prefabrication, there is already extensive premanufacturing and precasting of materials into larger elements of floors, walls, ceilings, roofs, and finish. Because of the rapidity with which they can be installed or dismantled for erection elsewhere, the popularity of prefabricated buildings has grown rapidly since World War II. They have filled the urgent need for more space, but their widespread use as permanent buildings is not feasible until mass production lowers present costs.

There is increasing emphasis on the belief that the school should be constructed of good materials with simplicity of design. Less stress should be placed on the idea of creating an impressive effect with expensive exterior ornamentation or huge auditoriums and gymnasiums which are used infrequently by the school. If these out-size rooms are included in the school structure, their use and cost should be shared with the community. The primary consideration of the groups who control school planning should be to provide space and facilities sufficient for the daily needs of the pupils and the teachers. Almost without exception schoolmen have recognized the need for larger classrooms.

Design

The continuing trend toward functional design to fit the modern educational program has produced many changes in school planning. Noteworthy developments in functional design are the tendency toward larger school sites with ample space for recreational and educational areas; and the tendency toward L-shaped, finger type, or even campus-plan, one-story buildings. There has been a prevailing idea that there is still plenty of land on which to erect modern one-story schools, but according to Haskell (22) it is an erroneous idea when applied indiscriminately to any large city. Many cities either cannot find such a large site that is at all reasonable in cost, or if they can it is likely to be a rocky, irregular slope. In seriously congested districts, the two- or three-story school is the only possible answer to the problem. Pangburn (29) stated that even where plenty of land is available, proximity of a park to a school site is both useful and economical.

Several writers described the trends in design which have impressed them. Engelhardt (18) described functional spaces, playground and garden areas for kindergarten and primary grades. Mitchell (26) recommended: (a) more free floor space, (b) plenty of open bookcases, (c) movable desks, (d) tables, (e) wall space for maps, (f) electrical outlets, and (g) sinks for classrooms. Viles (39) discussed the measuring of school-building utilization and advocated the use of the pupil station unit

as being useful and accurate in designing instructional spaces. Hamon (21) stated that there are trends in new designs toward providing larger sites, larger teaching areas, facilities for convenient storage, better seeing conditions, one-story plans, and maximum flexibility and expansibility. Viles (40) stated that the plant must be a convenient and attractive tool. He stressed simplicity, plenty of space and facilities, and provision for the health and well-being of children.

Adams (1) stated that provision for large classrooms and space for activities should come first. He suggested saving by: (a) eliminating basements, (b) building schoolhouses on concrete slabs covered with asphalt tile, (c) using trussed roofs with which bearing partitions may be eliminated, and (d) using better acoustical materials whereby thinner walls may be made possible. He desired more homelike classrooms, movable chairs, cheerful wall colors, and colored asphalt tile floorings. He suggested the use of wings with bilateral lighting to improve classroom lighting. Administrative quarters, assembly areas, and gymnasiums should be located so as to be easily accessible to the street, and so that they may be serviced separately for activities not requiring the whole building.

Cyr and Linn (15) supervised the preparation of a series of plans depicting modern design for school buildings and rooms for classes and other activities to be used in rural communities.

In the *School Executive* for January 1949, a number of outstanding authorities made exceptional contributions which provide an organized treatment of school-building design for the entire school-plant area. In a section on trends in types of units, Stanhope (36) noted the general trend toward horizontality and single-story construction. He illustrated nine advantages of this type of school-building design. Cherry (10) illustrated two small schools: (a) a neighborhood primary school adapted to the needs of little children, and (b) a rural school with almost every space adaptable to multiple use. Engelhardt (19) described a home-school unit designed to supplement the elementary school, and also adaptable to use as the first stage of a complete elementary school. Leggett (24) presented a community school functionally planned thru the cooperation of the school staff, community representatives, architects, and educational consultants. He described five functional areas.

In a section on structural design, Smith (35) dealt with trends concerning the interrelationships of spaces in school-plant design. He included relationships between: (a) the school site and the community, (b) the building and the site, (c) the departments within the school, (d) the spaces within the department, (e) the spaces within the individual rooms, and (f) structural materials in three types of classrooms. Caudill (9) pointed out four strong current trends in structural designs and materials. He predicted greater use of: (a) repetitive rigid frame, structural units of steel, wood, or concrete; (b) light, thin removable nonload bearing partitions; (c) fewer and larger prefabricated units of construc-

tion; and (d) speedy erection technics to reduce labor by assembly line methods.

Van Nuys (38) stated that to achieve flexibility within the building, it is necessary to design lighting, ventilation, fenestration, and structure on a modular basis. Cochran (14) illustrated the multiple use of spaces for different parts of the educational program and for community purposes. Bursch, Gibson, and Wright (8) advocated: (a) more floor area per student, (b) a more efficient use of all available space, and (c) modular construction using nonstructural partitions.

In a section on physical well-being, Clapp, Gibson, and Wright (12) discussed the relation of design to classroom lighting showing how to achieve controlled and balanced brightness with natural and artificial lighting. They presented illustrations of one- and two-story designs with single- and double-loaded corridors. Essex and Gilson (20) advocated simple ventilation, using principles of design rather than intricate and expensive equipment.

De Shaw (16) classified trends in the development of school sites as more acreage per school, greater utilization of sites, and community and school use of property.

Multipurpose Design

A series of articles in the *Architectural Forum* for October 1949, by the editors and other leading authorities, dealt comprehensively with the school-plant problem. It was noted that present educational philosophy stresses the need for spaciousness in a classroom. It was predicted that more medium-sized schools would be constructed and fewer large or very small schools. It was stated that the road toward better schools is thru long-range functional planning, integration of design and engineering, industrialized building, multiple-use of space, building code modernization, and new plan types.

The *Architectural Forum* (4) stated that, while former standards called for 15 square feet per pupil, the current desired requirement is 30 square feet. A trend was noted toward rooms that are about 30 feet square. A room with these dimensions provides 30 square feet each for 30 children. A square room is economical because it offers the greatest area with the least building material. This shape of area is flexible because it may be subdivided easily without partitions into a rectangular main recitation area, and two narrower rectangular spaces suitable for activities. Such subdivision would be aided by movable storage cabinets.

A multimodular design was described with a 16-foot structural module, four-by-four floor and partition module and a two-by-two foot ceiling module. This design would provide for greater flexibility and ease of maintenance and repair by keeping structural components, partitions, storage cabinets, and services mutually independent. Such integration of design would also allow repairs or changes in one or more of the elements without destroying the effectiveness of the others.

The *Architectural Forum* (3) described a situation which could be duplicated on the outskirts of almost any city. A new residential neighborhood was built up by young married people. Soon there was a demand for elementary schools, later for secondary schools, then for neither as the people grew older. If designed flexibly a school building could be used first for elementary, then secondary grades, and finally dismantled for erection elsewhere for school or for industrial use.

In a similar example of the evolutionary use of a school, Shunck (33) told about an all-purpose building which was designed to be used successively to house senior high-school students, later to provide space for high-school shop, music, administration offices, and finally to become a center for district-wide administration, supply, maintenance, and bus storage and repair.

The *Architectural Forum* (5) continued by describing three multi-use corridors: (a) a single-loaded type which was widened to allow for workroom alcoves opposite the classrooms with an open cafeteria at one end, (b) a double-loaded type having the widened interior between two rows of classrooms serve for exhibits, recreation, lounging, or lunch depending on the time of day, and (c) a combined multi-use room and corridor in the middle of a round type plan. Other multiple uses of special areas were indicated by the *Architectural Forum* (7). In the *Architectural Forum* (6) a description of a method of combating shifting needs for buildings by using a transportable school which was more than just a demountable building was reported.

Clapp (11) concluded that while building codes doubtless are necessary to prevent the construction of unsafe structures by incompetent or unethical designers or builders, they should not contain rigid restrictions which hamper or prevent worthwhile developments in design. He defended the one-story school by saying that it is safe, economical, and provides easily for the isolation of disturbing (to others) activities, and for adequate daylight in wider classrooms. He praised the National Council on Schoolhouse Construction for this organization's work on the revision of the *Guide for Planning School Plants.*

Nowicki (28) has challenged the imagination by presenting plans of two buildings embodying much advanced design including compact plan, short periphery, short communication lines, and multi-use of spaces. One was based upon the repetition of a standard bay which may be constructed of wood, steel, or concrete. The other was a circular plan which may circumvent previous engineering difficulties by using the technic of pouring concrete roof slabs on the floor and raising them hydraulically into place. Nowicki described a design by which plastic bubbles inserted in the roof provided diffused top lighting.

Materials

Altho wood, concrete, steel, glass, and brick are still being used more than other products, new materials are competing with the old in the

fabrication of many parts of the school buildings. Many of the materials in use are not entirely new but incorporate improved combinations or different applications of known materials. By using various substitute ingredients such as cinders, slag, light-weight aggregates, or vermiculite concrete blocks, have been given new qualities such as lightness, strength, hardness, or insulating properties. By finishing the blocks themselves, costly layers of other materials have been eliminated. Plastics are being combined with industrial wastes or other fillers to make materials for use as plastic tile flooring, composition boards, and table tops.

Stoneman, Broady, and Brainard (37) stated that in addition to the use of older materials of wood, metal, and ceramics, plastics have been used increasingly for interior trims and many minor purposes. They also stated that penetrating seals and oil paints are still the most satisfactory materials for floor finishes and paints. Smith (34) discussed material from the standpoint of five factors which influence selection of materials: (a) initial cost, (b) ease of maintenance, (c) acoustical properties, (d) light reflecting properties, and (e) adaptability for flexibility. He presented two tables concerning the properties and uses of materials. In the first, he rated many materials according to eight properties, and in the second, he gave ratings to the materials for use in various types of rooms.

Johnson (23) stated that materials have a profound influence on design. He discussed the costs of exterior materials and indicated that materials should be selected from the standpoint of economy, availability, and speed of construction. Clark (13) stated that schoolmen should consult school-building indexes so that they will not be deceived by unjustified increases of bids which have a tendency to rise faster and farther than actual costs of material and labor. The greater efficiency and speed apparent in presentday methods and procedures should tend to keep school-building costs down.

Linn (25) classified types of floor materials as wood, masonry, and resilient composition and gave many examples of each. He listed 12 points to use in the selection of materials. He discussed where and how to use and maintain different types of floor materials. Engelhardt, Engelhardt, and Leggett (17) devoted a chapter of their book to a comprehensive treatment of interior materials, floor and wall finishes, and doors for all types of buildings. Perkins and Cocking (30) used several sections of their recent book for the discussion of design and materials for floors, roofs, and structure. The American Association of School Administrators (2) gave a chapter in *American School Buildings* to materials and construction in relation to utility. It was stated that materials should be selected with a view toward ease of maintenance, and that wherever possible materials indigenous to the area should be chosen. Experience with materials for various purposes in school building was reviewed. The review included sections on materials for different floors, interior and exterior walls, windows and exterior doors, and acoustical treatment.

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CHAPTER V

Mechanical Facilities

JOHN H. HERRICK and PAUL W. SEAGERS

DURING the period covered by this review, there has been continued high interest in problems of school lighting and somewhat lesser emphasis on other mechanical facilities. School sanitation in particular has received little attention. The majority of the articles in the educational literature dealing with all mechanical facilities was exhortatory or descriptive of some prevailing practice; very little critical research was reported.

School Lighting in General

So many factors enter into the evaluation of good visual environment that our methods of evaluation need considerable refinement. Considerable research is now being carried on by the members of the Illuminating Engineering Society and the National Council on Schoolhouse Construction as well as by many private corporations. This constant evaluation and criticism of old methods and procedures is bound to make for better schoolroom lighting. Folsom and Biesele (29) pointed out some of the problems encountered in making accurate measurements and have gone so far as to suggest newer methods and instruments for making measurements. Darley (24) suggested that reflected glare reduces the visibility of the task. He stated that both reflected glare and imperfect binocular fixation can be improved by: (a) lower source brightness, (b) lower candle power from the contributing source area, (c) increased task brightness, and (d) improved task characteristics. Luckiesh (48, 49, 50) stated that the threshold foot-candle level depends on the individual, on the task, and on the seeing conditions. He expressed the opinion that we should have lighting conditions much better than the threshold levels; however, he doubted whether we could ever reach ideal levels. He expressed great interest in light and vision as tools of performance for seeing, and gave basic consideration to the border line between comfort and discomfort in visual field brightnesses. Allphin (1) made an intensive study of the brightness engineering calculations as set forth by Harrison, Moon, Spencer, and Logan. Tinker (69) was very critical of the standards now used for effective and easy seeing. He claimed that psychologists should have been brought into the determination of these standards. He also said that frequently the high intensities that have been prescribed have been surplus intensities rather than useful intensities. Hoffman (34) supported Tinker's theories and criticized both the experimental and statistical technics which have been used in arriving at the high standards we now have. Birren (17), a color specialist, criticized the theory of uniform brightness and claimed that deep tones are not only decorative

but a definite aid to acuity. He took issue with the Illuminating Engineering Society on their present standards. Bitterman (16) claimed that existing lighting standards were on unstable ground and that we need much more research. He went definitely into the problems of visibility as related to readability. Likewise, Almack (3) criticized current architecture and lighting standards as not being a product of specific investigation. The same holds true for Winkler and Neidhart (78); however, much of their criticism was directed to the louvers of the lighting fixtures.

The September 1948 issue of *Illuminating Engineering* (36) gave the American Standard Practice for lighting schoolrooms. Essex (27) discussed rather fully all phases of general lighting including construction, room arrangement, and decoration and gave good examples of the application of the American Standard Practice. Gibson (31) gave a practical method for teachers to use in checking their lighting conditions and made suggestions for the remedy of the defects. Kahler and Meacham (39) made a strong plea for correlation of brightness ratios and decoration. They stressed that the decorator consider contrast in both color and brightness to establish character of design. They insisted that we must have more coordination between the lighting engineer and the decorator with perhaps some compromise on the part of each. Moon (51) presented an interesting discussion on the use of luminous ceilings, louvered ceilings, diffusing globes, troffers, and other types of lighting. He suggested that regardless of what type of lighting is used the decorations are extremely important. Logan (46) discussed the distribution of light in the field of view, subdividing this field of view into both the upper and lower glare zones. His formulas were based upon this subdivision. Seagers (63) incorporated in a bulletin principles of good practice and showed the need for the coordination of the efforts of the color specialists with the lighting engineers. This bulletin includes reports from the participants of the Indiana Illumination Conference of 1950. Spencer (65) described the relighting of three rooms in Tufts College. She gave a highly technical but interesting treatment. According to Nickerson (53) more attention should be given to the Munsell value scale of colors, because brightness of color alone cannot adequately give all the desirable qualities of that color.

Altho it is rather risky to attempt to judge illumination in terms of pupil achievement, nevertheless a number of individuals have undertaken to do so. Two of the most interesting discussions of this point were made by Allphin (2) and Turner and Brainerd (71).

Natural Lighting

Natural lighting is frequently considered expensive to get into a room and expensive to control after it is there. Nevertheless it is recognized that some natural lighting is desirable for rooms that house children for any length of time. Schmidt (61) gave an interesting account of an engineering study of a well-lighted classroom, while Kump (40) explained

the various methods of bilateral lighting, including clerestory methods of getting better and more daylight. Johnson (38) was interested in the monitor-type roof for economical daylight. Gibson (30) explained the difference between daylight and sunlight and said that even on dull days we usually have enough foot candles or foot lamberts of daylight in all localities if we only know how to use them. Biesele (14) went into a thoro explanation of the newer developments of daylight in classrooms. Benford (11) explained the duration and intensity of sunshine. His explanation contributed valuable material and gave many interesting architectural applications. In an excellent article on glass block, Viles (74) attempted to evaluate some of the work by Hugh Paul.

Planned Lighting

Walters (76) showed how existing conditions in schoolrooms can be improved by a little careful study and the application of principles now known. Tinker (70) stressed the margin of safety above critical seeing. Sharp (64) pointed out some of the inconsistencies of standard practices and drew attention to the over-all planning of lighting. He felt that reflected glare is frequently ignored in trying to obtain high quality lighting. Putnam (59) gave an interesting explanation of the history and the development of the American Standard Practice for Schoolrooms. Putnam (58) also showed how specific lighting installations had been set up and indicated the results of meeting recommended standards. Pearson (54) made a study of the plastics and told how they could be used for decorative effects in connection with lighting. Moon and Spencer (52) gave an explanation of methods for determining the lighting from luminous ceilings. Kuntz and Sleight (42) showed the significance of higher lighting levels for subnormal acuity as contrasted with those with normal acuity. This has many implications for setting up sight-saving rooms. Fallon and Allphin (28) discussed the model classroom, using a combination of planned lighting and louvers for daylighting. Darley (23) traced the development of quality in lighting, especially in connection with the increased glare associated with increased foot candles. He also gave a useful explanation of the brightnesses of the different types of fluorescent fixtures from different angles. The use of louvered ceilings was championed by Potter and Oetting (56). Benson (12) also gave a critical discussion of the use of the louvered ceiling. Recent developments in the luminous ceiling were discussed at great length by Beckwith, Peterson, and Moon (10), Spencer (66), and Benson and Church (13). These discussions indicated a new trend in school lighting once the cost of the luminous ceiling is brought down to a figure comparable with the ordinary lighting fixture.

Cold cathode lighting has been much discussed for the past several years. Two of the most interesting articles were written by West (77) and Lewis (43). West's article gave many good characteristics of cold cathode lighting, while Lewis' article indicated different types of installa-

tion. Cold cathode lighting is still in the experimental stage so far as general schoolroom use is concerned, unless protected by louvers. Harrison and Meaker (32) developed some new glare ratings including formulas which take into consideration all sources of light. These, when simplified for general use, will be of considerable value in laying out a more glare-free educational environment.

Electrical Facilities

There has appeared in the literature some difference of opinion regarding central sound systems. Perkins and Cocking (55) stated that equal results at less cost could be achieved with room radios rather than a central system. Other authors continued to assume the merits of central systems and described how to make them more effective. Bildersee (15) described the characteristics of good public address equipment and the conditions necessary for proper installation. The *Architectural Record* (7) published plans to implement the recommendations of the United States Office of Education and the Radio Manufacturers of America. Cumming (22) also made detailed suggestions for installation. Sullivan (68) predicted the early development of public address systems that would obviate the need for special wiring in the building. Louis (47) discussed several ways of using a public address system, while Pratt (57) described the use of such equipment in the administration of group tests.

Lewis (44) advocated television conduit in new construction and forecast the development of television systems similar to central public address equipment.

Detzer (25) described the use, in at least eight states, of telephone facilities to enable bed-ridden pupils at home to hear and participate in discussion in their classrooms, and one article (6) discussed a telephone-television combination to serve the same purpose.

Plumbing and Sanitary Facilities

Brown (18) made a detailed comparison of the plumbing and sanitary requirements of the several states with the recommendations of the National Council on Schoolhouse Construction and found little agreement.

There was general agreement in the literature that toilet rooms must be brought out of basements and placed in more convenient and pleasant locations. Several authors discussed proper heights of plumbing fixtures (8, 26, 72). New York State, for example, recommended facilities for each sex on each floor (72). While New York State advocated baby-size water closets for kindergarten and primary grades, Perkins and Cocking (55) maintained that they were too small for comfort and not worth buying. The health implications were not discussed.

Perkins and Cocking (55) saw a trend toward drinking fountains in each classroom. Irmiter (37) and Campbell (21) discussed ways of controlling variations in flow of drinking fountains.

Viles (75) deplored the level of sanitation commonly found in school buildings. A committee of the American Public Health Association was reported (4) to be working on a grading system to rate the status of school sanitation, but apparently had made no substantial progress. Sturkie (67) reported an evaluation of sanitary conditions in the school buildings of Lynchburg, Virginia, and indicated a prevalence of sanitary defects in terms of the somewhat outmoded standards used.

Heating and Ventilating

Kump (41) discussed the principles of radiant heating and their application to school buildings. He stated that few pipe failures had occurred in installations now 10 to 15 years old. Low operating costs and comfort were among the advantages cited. Hosford (35) and Bursch (19) also reported favorably on this type of heating, and the latter reported a definite trend toward panel heating in California.

Lewis (45) discussed his experience as an engineer in converting old, hot air furnaces by installing steam or hot water convectors to heat the air. He also advocated hot air in new buildings, even if one-story construction.

Radder (60) discussed ways of keeping down heating costs by proper use and care of equipment, and Barbour (9) gave practical suggestions on boiler room safety.

Viles (73) presented a generalized discussion of heating and ventilating for classroom teachers.

Buttolph (20) discussed the use of ultraviolet lamps in school buildings with particular attention to installation in ducts. He also pointed out the need for proper painting to avoid objectionable reflectance for classroom ceilings. Hodges (33) reviewed favorably test data on the use of germicidal lamps in schoolrooms. The Council on Physical Medicine of the American Medical Association (5) continued to refrain from endorsing ultraviolet lamps for classroom use, but stated that such use was on the border line of acceptable applications. Seagers (62), while indicating that the use of such devices was still experimental, did indicate some beneficial results if used with proper precautions. He indicated that the use of aerosols was likewise still in the experimental stage.

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CHAPTER VI

Financing School-Plant Developments

DAN H. COOPER*

THE several excellent studies of school-plant finance which have been published in the past three years provide much valuable information for the use of school administrators, members of boards of education, architects, school patrons, and taxpayers in meeting their school development problems. The available studies not only have demonstrated the practical value of research in school-plant finance; they also have served to open the field in an exploratory fashion. Much good would surely be derived if expanded research resources could be made available for school-plant finance studies in state departments of education, in the U. S. Office of Education, in universities, and in research bureaus elsewhere. The problems of school-building finance are not the only educational problems for which an expanded program of research is needed; but the tremendous amount of money necessary currently for school-building construction has created a situation which urgently needs thoro and detailed research analysis.

The literature on school-plant financing published during the period covered by this chapter may be classified under the following headings: (a) expenditures for school-plant developments, (b) predictions of future expenditures, (c) predictions of future financial resources, (d) state and federal contributions to school-plant financing, (e) unit costs and cost indexes for school-plant developments, (f) methods of economizing on the cost of school-plant developments, and (g) nonconstruction costs in school-plant developments.

Expenditures for School-Plant Developments

The magnitude of the expenditures which have gone into new school buildings and sites in recent years may be appreciated from figures which Cocking (10) collected from 2370 school systems and from colleges and universities. Sixty-one percent of the school districts reporting to Cocking had constructed new school buildings since World War II or were planning to build in 1949. During 1949, 3316 public school buildings were constructed, at a cost exceeding $1.038 billion. During the same year, contracts were awarded for 879 college and university buildings, at a total cost of over $352 million; and these figures did not include colleges with enrolments of less than 1000 students. The total expenditure in 1949 for public elementary- and secondary-school plant developments, and for

* The author is indebted to N. LeRoy Nelson, research assistant, State University of Iowa, for assistance in gathering references.

college and university buildings, was estimated on the basis of the evidence at $1.4 billion.

Cocking's research provided information not only on the nation as a whole, but also for the major regions within the United States. Interestingly, the expenditures for public elementary- and secondary-school buildings did not always parallel the volume of building in terms of numbers of new schools from region to region. From 1945 thru 1949, the school districts reporting from New England constructed 7 percent of the total number of buildings at 6 percent of the total national expenditure; the Middle Atlantic school systems reported 19 percent of the total number of buildings which accounted for 36 percent of the total national cost; the school districts reporting from the South were responsible for about 26 percent of the total number of buildings and for about 19 percent of the total expenditures; the Midwest school districts built about 26 percent of the nation's new schools for about 23 percent of the nation's total expenditure; and the reporting school districts of the West built 22 percent of the nation's new schools for 16 percent of the nation's total expenditure. The Middle Atlantic school systems seem to have paid a much larger proportion of cost for the number of schools erected; while the school districts of the South and West have obtained proportionately more school buildings for their share of the national expenditure.

Estimates of the expenditures needed for new school-plant developments in the nation, while always staggering to the imagination, have been increased in the more recent investigations. Linn (33) estimated the cost of necessary school buildings at $5 billion for the decade 1948-57, based on a probable increase of 5 million pupils in elementary and secondary schools, and assuming a capital investment of $1000 per added pupil. The interest alone on this expenditure, assuming amortization over 20 years with interest at the rate of 2¾ percent, was calculated at $1.375 billion. The *Nation's Schools* (43) in February 1948, reported an estimate by the U. S. Office of Education of $6.6 billion for immediately needed new public elementary- and secondary-school buildings, with an additional $800 million necessary for nonpublic schools, $3.5 million for colleges and universities, and $2 billion to accommodate anticipated enrolment increases. The 1948 yearbook committee of the American Association of School Administrators (2) raised previous estimates of expenditures for capital outlay to $1.25 billion annually, or apparently to a total of $12.5 billion over a 10-year period. In October 1949, Hamon (25) published an estimate of $10 billion as the necessary expenditure of the forthcoming decade for new public elementary- and secondary-school buildings. Morphet (36) estimated in 1949 that $11.25 billion (sic, $11.125 billion) would be needed within the decade, exclusive of interest and other necessary charges for bonds. Morphet's figures are similar to the statistics compiled by Chase and Morphet (12) from questionnaires returned from the 48 state departments of education regarding school-building needs. In both of these studies to which Morphet contributed,

attention has been called to the necessity of adding to actual building cost figures from $2 billion to $2.25 billion for interest and other charges in connection with bond issues.

On the basis of revised school enrolment forecasts and more recent figures on construction costs, Hamon (24) calculated an estimate of $13.5 billion for public elementary- and secondary-school buildings for the 10-year period beginning in 1950. Provision was made in this estimate for anticipated enrolment increases, for the replacement of obsolete and unsafe buildings and classrooms, for district reorganization, for extensions of education to include more kindergarten and junior college classes, and for supplementary spaces such as libraries and lunchrooms. *School Management* (48) published an estimate similar to this figure.

After adding an estimated $1.5 billion for nonpublic elementary- and secondary-school buildings to the initial sum, and an estimated $5 billion for college and university buildings, Hamon reached a grand total of $20 billion needed for the construction of educational buildings in the next decade. Translated into labor, this estimated financial need was calculated as representing the labor of 5 million man-years to produce completed buildings from raw material.

An allocation of the equivalent of 500,000 men annually for the next 10 years to school-building construction in this nation should be a problem of more than academic interest to manpower specialists of the nation. The international tension, which has deepened since these estimates of need were made, is as likely to increase the school-building need as to relieve it, particularly at elementary- and secondary-school levels. Significantly, Hamon (24) indicated that his estimates of financial and manpower needs are probably still too conservative.

In addition to these studies of the amount of money needed thruout the nation for school buildings, there have been studies smaller in scope. Many survey reports have included estimates of the cost of school-plant developments needed for individual local school districts, as well as for state school systems, systems of higher education, and nonpublic school systems. This survey literature has not been included in this review of research on school-plant finance. An example of an estimate of needed school-building construction for a single state is that by Clapp (7), indicating that $400 million would be required "for the cost of placing Michigan's total school plant in reasonably good condition in the next few years."

The cost of meeting the school-housing needs of city school systems in 1947-48 has been estimated by the Research Division of the National Education Association (42), on the basis of reports from 1600 superintendents of schools. An outlay of about $1.5 billion was found immediately necessary to relieve overcrowding in classrooms, to eliminate half-day sessions, and to replace substandard facilities.

All of the estimates of future expenditures for school plants are subject to some margin of error; and certainly the future may bring some sur-

prises to upset predictions. An important feature in these predictions, however, is that they are based in large measure on factors which are relatively definite. Evidence is at hand that half-day sessions are in operation, that class sizes exceed recognized standards, that substandard classrooms are in use, and that incoming kindergarten and first-grade groups of children will be larger for the next few years. Some of the factors which will influence school-plant expenditures may be modifiable; but other factors which form the basis of prediction are already established. Consequently, there is an element of inevitability about the forecasts of present and future building needs which should serve to encourage serious efforts to cope with their predictions.

Predictions of Future Financial Resources

An effective antidote to public reaction resulting from predictions of needed future expenditures would seem to be accurate predictions of future financial resources for necessary plant developments. Fortunately, several encouraging reports, indicating that this nation can easily afford to meet its building needs, have been made. The 1948 yearbook of the American Association of School Administrators (2) reviewed evidence regarding the probable national income during the next decade, to show that the nation can afford capital outlay and other expanded expenditures for education without exceeding the percentage of the national income which was devoted to education in the 1930's; and without equaling the percentage of the national income devoted to education by some foreign countries. In harmony with other pronouncements of the American Association of School Administrators, this yearbook reminded its readers that expenditures for good schools do not in any case constitute a drain on national income, but that these expenditures are investments which result in ever higher standards of living. By this view this nation may continue to progress toward ever higher economic levels only by ever more liberal expenditures for all phases of education.

During and just prior to the period covered in this review, economists have been making exhaustive studies of the nation's ability to support progress. Each of these reports presented dramatic and abundant evidence of the potential capacity of our nation to produce all the wealth needed for good schools and for a multitude of other desirable things.

A study by Dewhurst and others (15) under the sponsorship of the Twentieth Century Fund, summarized for popular distribution by Carskadon and Modley (5), examined the nation's productive capacity from 1850 to 1947 and projected the observed trends forward to 1950 and to 1960. Provided that the nation would have neither war nor serious depression, the national income at 1947 prices likely to be achieved in 1950 was found to be $165.4 billion—an increase of about $45 billion since 1940 or of $75 billion since 1930. By 1960 the probable national income at 1947 prices was found to be $190.3 billion—another increase of about $25 billion within a decade. Even if war should come, the nation was

found capable of exceeding peak World War II production levels by 50 percent.

These forecasts of national productivity were predicated on rather conservative assumptions, with the result that the estimates for national income in 1960 were actually exceeded in 1950. The actual 1950 national income according to computations made from data in the U. S. Department of Commerce *Survey of Current Business* (51) is roughly $220 billion in 1947 values, in contrast to the $90 billion income of 1930 or the $121 billion income of 1940. Even without the stimulus of the Korean War during the last half of 1950, the 1950 national income in 1947 dollars would undoubtedly have exceeded $200 billion. This means that the nation has more available resources than ever before to finance such developments as new school buildings; and that progressively the nation becomes ever more capable of meeting its needs.

Moulton (38), in a report for The Brookings Institution, posed the question: So far as natural resources and productive capacity are concerned, might the United States a century hence support a population double that of the present on a plane of living eight times as high as that now prevailing? The answer, at the conclusion of a chapter devoted to analysis of future economic prospects, is:

". . . There can be little doubt that the onward sweep of science and technology as a whole is such that in one way or another scientific advancement as applied to the processes of production could yield results of the magnitude projected at the beginning of this chapter" (p. 246).

The results projected by Moulton for education within the century are even more startling than his general prediction of a plane of living eight times as high as that now prevailing. His reasoning and his findings are expressed in the following quotation:

"The allocation of expenditures changes materially as income rises. Budgetary studies reveal that the great bulk of expenditures in the lower income ranges goes for food, housing, and clothing. Thru the middle- and higher-income brackets, the percentage spent for the basic necessities of life falls, while the proportion going for so-called conventional necessities and luxuries rises. . . .

"Thus on the basis of actual experience, it is possible to indicate roughly what the volume of expenditures for major classes of goods and services would be if the population were doubled and the plane of living were eight times as high. . . . Under these conditions expenditures in the various categories would be multiplied as follows:

Food and nutrition—about eight times
Shelter and home maintenance—about sixteen times
Attire and personal care—about twenty times
Health and education—about thirty times
Recreation and travel—about thirty-three times" (p. 204-205).

Clark (9), in commenting on the Moulton study, computed the annual expenditure for school plant under a thirty-fold (sic., thirty-three-fold)

increase at $17 billion a year, in contrast to the record-breaking $1.4 billion actual expenditure of 1949 as reported by Cocking.

The accumulated evidence of the past triennium regarding future financial resources in the nation is abundant and exciting. The productive capacities of which the nation is capable seem even more fantastic than the school plant and other needs which should be met. After studying the evidence for a time, both of needs and of resources, the reader is likely to feel that the only thing which may prove small and limiting in the future is one's own vision and courage.

State and Federal Contributions to School-Plant Finance

It is one thing to show that the nation has progressively larger resources with which to build schools; but it is something else to find ways of obtaining for schools the necessary portion of the national income. Clark (9), after discussing the economic prospects outlined by Moulton, expressed the prevailing and often repeated view of educators and others on this matter when he wrote:

"We have probably passed the safe limit of local taxation. Greatly expanded expenditures for education will depend then upon revenue collected by the state or national governments" (p. 62).

Many viewpoints and several research studies along this line have been reported. *School Management* (48) outlined principles which are believed to be sound for any program of federal aid for school-building construction. Arguments in behalf of federal and state aid for school-building construction have been presented by Eckles (16); Hamon (24); Hewes (28); McLure (34, 35); Morphet (36); Perkins and Cocking (44); and Thurston (52).

Lee (32) contributed a doctoral study of the early history of federal aid to education. He recounted the late eighteenth and early nineteenth century grants of land and other resources from the federal government, which aided many communities in building their first schoolhouse; and he reported the controversies of the 1870's regarding the Hoar Bill which included, as part of a national system of education, provisions for federal construction of school buildings. Hewes (28) chronicled the school-building achievements of the federal government by means of the PWA, the WPA, and the Federal Works Agency Advance Planning and Lanham Act programs, wherein many thousands of new school buildings and additions to school buildings were constructed between 1933 and 1948. Hewes (27) also reported the desperate situations of some 395 school districts serving areas where federal governmental activities have attracted many families with children, but where the government holds much of the property, including frequently the residences of the families, without being obligated to pay local school taxes. These situations should be relieved by recent federal legislation described by Hamon (23) to provide funds for (a) grants to states for school-building surveys and (b) grants to school districts overburdened with enrolments resulting

from war, defense, and federal activities. A wealth of data and illustrations on the need for more schoolhousing in localities and in the nation, and on the merits of the bills before the Eighty-First Congress to provide federal assistance for the construction of school buildings, appeared in the published hearings (11) on the bills.

Individual programs of state aid for school-building planning and construction have been described by Bursch (3); Cocking (10); Dawson (14); Simpson (50); Morphet, Reller, and Bursch (37); *School Life* (47); the National Commission on School District Reorganization (39); and the 1949 Yearbook Commission of the American Association of School Administrators (1). Three comprehensive surveys of state programs of financial aid for school-building construction were compiled by Chase and Morphet (12) from their questionnaire study of the 48 state departments of education for the Council of State Governments; by Hamon (25) in an article describing the programs of aid in 19 states now providing some financial assistance to local school districts for capital outlay; and by Jarvis (30) in his doctoral dissertation, *Methods of Financing School-Building Construction in the Forty-Eight States.*

Jarvis (29) also submitted 60 features of federal-state-local plans for school-plant financing to specialists for appraisal. On the basis of the replies he described an ideal plan of school-building finance. He found that the states ranged from 65 percent to 21 percent of perfection in their methods of school-building finance when rated against the ideal.

Morphet, Reller, and Bursch (37) have prepared a report of a regional conference held at the University of California on the financing of school-plant developments. Six work committees at the three-day meeting considered various aspects of state participation in school-building financing. This report has merit as an account of the pooled wisdom and thinking of experienced school-building specialists from several states.

Several general conclusions can be drawn from the literature on state and federal contributions to school-plant finance: (a) there has been an unusual concentration of attention on the subject; (b) in all the volume of writing on the subject, including the report of extensive hearings of federal aid for school-building construction before a subcommittee of the United States Senate, there has not been a single dissenting voice against state and federal aid for capital outlay for schools; (c) the principles of procedure set forth in the literature for state and federal-aid plans seem to be widely accepted and understood; and (d) in spite of the seemingly unanimous approval of state and federal aid, progress seems disheartenningly slow, even tho some beginnings have been made.

In view of these conclusions, the task ahead seems clear. Here, in the achievement of state and federal school-plant aid, is a project endorsed by virtually all educators and many other persons, and enjoying a high priority of urgency and importance. Upon this project the most careful and intensive of investigations, and a wide dissemination of factual evidence and viewpoint, seems warranted. Much of the evidence still needed,

especially from states where school-plant data have not yet been systematically procured, may come from official governmental studies; but additional investigations and a wider appreciation of the significance of the evidence can be supplied by many contributors.

Unit Costs and Cost Indexes

Estimates of the anticipated costs of building, comparisons of the costs of buildings, trends in building costs, and methods of economizing in costs may be discussed in terms of some unit of cost. The unit may be the classroom, the classroom equivalent, the pupil, the "weighted pupil," the cubic foot, or the square foot of floor area. Trends in these unit costs may be reported in the form of index figures. Most new school buildings of consequence are described in the professional literature upon completion, and in the more helpful descriptions some type of unit cost data are provided.

One of the most helpful and frequently quoted studies of costs is a cost index figure published every two months in *School Executive* by Clark (8). Based on 1939 costs, the April 1950 index stood at 181.8 with further rises anticipated. Eckles (16) and Exton (21) provided tables prepared by N. E. Viles of the U. S. Office of Education showing an index of school-building costs ranging from 100 in 1913 to 480.2 in October 1948. Perkins and Cocking (44) reported on over-all construction costs from the January 1947 *Dunn's Review*, showing a rise from an index of 100 in 1914 until the comparable contemporary figure had exceeded 300. The *Research Bulletin* of the National Education Association (41) reported an index prepared by Boeckh and others, indicating the rise in construction costs since 1928. In all of these reports, the spectacular rise in building costs is apparent.

Eleven reports have been found which present unit cost figures for recent school-building construction. Engelhardt (20), and Perkins and Cocking (44), summarized cost per cubic foot for typical construction. The Research Division of the NEA (41) collected data on cost per cubic foot for 126 buildings completed, or for which contracts were let in 1947. Later, the Educational Research Service (42) reported cost per cubic foot for 69 school buildings completed during the period 1947-50. This publication also supplied data on the cost of purchase and preparation of site for 63 projects. Carlson (4) reported average cost per cubic foot for 29 buildings; and *School Business Affairs* (45) gave both cost per cubic foot and cost per square foot data for each of 11 buildings. Chase and Morphet (12) reported estimates of cost per cubic foot, cost per square foot, or cost per classroom unit from 31 of the state departments of education. Most of these estimates were reportedly based on systematic studies within the respective states.

School Business Affairs (46) has also reported per pupil cost figures for a group of 29 elementary-school, six junior high-school, seven high-school, and three college buildings surveyed in the *Engineering News-*

Record. The original study in *Engineering News-Record* (18) gave per pupil, per cubic foot, and per square foot costs. Information on the cost per pupil and per "weighted pupil unit" for 23 school-building projects was supplied by McLure (35).

The impressive feature of these unit cost reports is the wide variation in cost from project to project. Costs per cubic foot ranged during the period of these reports from 32 cents to $2.50 (42). Costs per pupil were reported ranging from $193 to $2044 (45). Even allowing for variations in reporting practices, these differences raise many questions. The Research Division of the NEA noted some variations in cost by regions; and the Educational Research Service classified its information by type of construction to show variations of cost in this respect. Clearly, as *Engineering News-Record* (19) pointed out, variation in educational adequacy is another reason for variation in building cost, especially when building cost is expressed in an amount per classroom or per pupil. Nevertheless, one of the deficiencies in school-plant finance research appears to be in the supply of detailed comparative studies of the reasons for differences in unit costs of construction.

A useful study of details in school-building costs has been provided by Harriman (26) in two issues of *Architectural Record*. Working from the contractors' cost sheets for recently completed buildings, the author presented cost per square foot of floor space and cost per classroom unit for (a) three types of exterior walls (glass blocks above steel frame sash, double glazing in wood sash, and single glazing in wood sash), (b) five types of roof structures, (c) three types of gymnasium roof, (d) three ceiling heights and three classroom widths, (e) one- and two-story building types, and (f) buildings with single- and double-loaded corridors. The most economical construction proved to consist of single-glazed wood sash walls, of nonfireproof pitched roof, of laminated timber oval roof arches in gymnasiums, and of one-story buildings with double-loaded corridors. An increase in span was found to yield a *decrease* in square foot cost in classrooms with ceiling height held constant. Harriman (26) concluded that the most economical type of building would be a one-story structure with double-loaded corridor, with a pitched roof of minimum height at the eaves, and with clerestory lighting above the corridor. (The latter, presumably, to permit wider and shorter classrooms.) Coming from an architect whose firm has designed schools over a period of 69 years in the cold-winter state of Maine, these conclusions are noteworthy.

Methods of Economizing on Construction Cost

The Harriman (26) study presented not only a penetrating analysis of factors affecting unit costs but also economy in cost. More studies like it should be made available to school administrators and others. Less objective, but quite suggestive, is a tabulation prepared by Christensen of the architectural firm, Kump and Falk, and published in the

Engineering News-Record (18). The table classifies materials for 35 features of a building under the headings (a) lowest cost, (b) medium cost, and (c) highest cost. For roofing, the low cost materials are roll roofing and asphalt shingles; the medium cost materials, split shakes and asbestos shingles; the highest cost, tile and slate. The article points out that economy is affected by quality, by completeness of initial development, by site development, and by the extent and complexity of utilities and services for a building.

A thought-provoking discussion of possible economies in construction and design was presented in the Twenty-Seventh Yearbook of the American Association of School Administrators (1). In contrast with the evidence presented by Harriman, the yearbook stated that large multi-story buildings of fire-resistive construction thruout will be more economical than one-story structures, if the same standards of construction are applied to the one-story structure. Many persons would be interested in a resolution of the conflicting positions on this point. Possibly the fallacy in the yearbook statement is in its implication that the same standards of construction should be applied to one-story structures as to multi-storied structures.

A protagonist on the side of the one-story building was Johnson (31). He argued the merits of a host of methods for achieving economy. Factual data of interest was presented on one point—the relative cost of several kinds of building material. Concrete block proved to be the most economical, at $9.50 per square foot of building for schools in the state of Washington. Other materials were listed as follows: frame and stucco, $10.57; brick, $11.57; brick over concrete, $12.50; frame, $12.50; brick over tile, $13.50; brick veneer over frame, $14.50; and solid concrete, $16.50. If these figures are typical, they should influence practice greatly.

Van Nuys (53) argued persuasively for contemporary design as a means of achieving economy. Defined as the architectural result of over-all planning in terms of the kinds of space needed for activities within a school, contemporary design was described as (a) avoiding the waste of superficial massive decorative effects; (b) eliminating the useless spaces resulting from a predetermined external form; and (c) reducing the inflexibility which, according to Van Nuys, often leads eventually to nonfunctional, yet expensive structures.

Nonconstruction Costs in School-Plant Developments

The financing of a school-plant project involves many items in addition to the construction costs. The yearbook of the American Association of School Administrators (1) on school buildings presented evidence to show that construction costs for nine typical developments were from 74.1 percent to 89.6 percent of the total initial costs. The remaining 10 to 26 percent of initial costs were used for legal advice, site development, architects' and engineers' fees, furniture and equipment, and miscellaneous.

In addition to these extra initial costs, interest on bonds and incidental expenses in connection with bonding may require large amounts of money. The AASA Yearbook (1) devoted the major portion of one of its chapters to principles and problems of bonding, giving particular attention to types of bonds, legal regulations applicable to school bonds, the establishment of a credit rating, the bond attorney, procedures in the sale of bonds, and the safeguarding of funds. Castetter (6) provided further advice on the principles and problems of bonding, describing many details of procedure and referring readers to a bibliography for more instructions.

Chase and Morphet (12) secured information from each of the 48 state departments of education on provisions in the various states relating to school-bond issues. Their table and summary of bonding limitations, voting requirements, approval regulations, and authorized purposes is a valuable source of information. For city school systems, information on provisions with respect to school-bond issues has been supplied by the NEA Research Division (40). Reporting data from 1892 school systems, the *Research Bulletin* describes the authority of the school boards to levy and collect taxes, and to issue bonds.

Since a critical element in most bond issues is the public campaign and vote by which the bond issue is authorized, several articles dealt with the public relations involved in bond campaigns. Typical of this literature was the study of Ohio bond campaigns by the Ohio State Education Association (49); and an article by Crosby (13). Both of these reports listed features which seem to contribute to successful bond campaigns.

Clark (8), in his regular feature article published every two months in the *School Executive*, provides valuable information on trends and current interest rates on school bonds. One of the bright spots in the picture of rising costs is the information from Clark showing current interest rates at an average of 1.93 percent in April 1950. This is a lower rate of interest than has been available to borrowers at any previous time.

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CHAPTER VII

School-Plant Operation and Management

JOHN E. PHAY and JAMES W. HUNT

PROBLEMS of operation, maintenance and insurance of the school plant, and school-plant rehabilitation as treated in the literature of the period covered by this review are summarized in this chapter. Actually little research has been done in school-plant management during the last three years. The educational literature in this area, for the most part, describes practices of individual schools on various topics included in the area. Such described practices may be extremely important, however, because in many cases, the described practice is the one accepted after other methods have been used and discarded. A bibliography for the entire area of school-plant management was prepared by Viles (42).

Personnel Problems of Plant Operation

A major study of school custodial services was made by Viles (39). In this U. S. Office of Education publication, Viles placed major emphasis on a training program for custodians. Units comprising a training course were suggested. Phay (31) described the condition of custodians in cities above 30,000 in population with respect to salaries and salary schedules, working hours, vacations, sick leave, retirement, tenure, and organized labor groups. He presented 33 recommendations in these areas.

Selection

Methods of selecting custodians and maintenance personnel were reported by Zepp (45) who suggested the use of what amounts to an intelligence test. The *Nation's Schools* recommended the use of a psychiatrist to determine a custodian's fitness to associate with children. Hopper (20) suggested that custodians be required to be certificated by an examining board. Advantages to the community resulting from custodian certification were safety, efficiency, and economy. In turn, the custodian profited in the improved dignity of his position and in greater job stability.

Custodial Training

The practice of providing courses for training custodians is increasing. Training programs have been provided by some state departments of education, cities, schoolboards, and institutions of higher learning. For those contemplating an inservice training program for custodians Bliss (10) suggested one approach. Crone (13) reports an inservice night school program for custodians that appears adaptable to most city school systems. For improving custodial efficiency, Hopper (19) sug-

gested sending some custodians to school each year at the expense of a schoolboard.

Viles (39, 40) described six types of training programs and suggested a program of study.

Salaries and Salary Schedules

The National Education Association (27) issued the second in a contemplated series designed to list salary information of operation and maintenance employees for school systems over 30,000 in population. The National Education Association found a general salary increase of $500 to $600 a year and a work-week decrease of two hours for school operation and maintenance employees in 1946-47 over 1942-43. Salary schedule provisions in 1948-49 for custodial workers in cities over 100,000 in population were reported by the National Education Association (28) for 17 cities. Covert (12) reported the practice of yearly determining the custodian's salary by an appraisal of salaries received by similar workers in other establishments. He stated that agreement on salaries was reached by representatives of the custodians and the administration.

Custodial Relations

Hynds (23) indicated the desirability of securing a good working relationship between custodians and school administrators. He suggested aids for improving relationships which included a labor-management committee. Barbour (8) suggested that schoolboards can do much to promote good feeling among custodians. The rating scale of the St. Louis janitorial and engineering staff was listed by the *American School Board Journal* (4). Barbour (7) suggested that administrators give assistance to custodians in their record keeping and suggested specific aid that will help the custodian with his records.

A movement for a new organization that will include all school-building operators was reported by Resch (32) who thought such an organization superior to separate organizations for janitors, custodians, and engineers.

The *Nation's Schools* (29) recommended the use of uniforms for school employees as an aid to morale, to add dignity to the position, and as an aid in promoting better personnel relations.

A system utilizing a roving caretaker, who goes from one school to another to relieve regular custodians for half-day periods, was described by Huggins (22). In Huggins' situation, the roving custodian was used so that the work week of the regular custodian did not exceed the normal number of hours.

Housekeeping

Most of the literature on methods of cleaning school buildings was confined to articles and pamphlets. An exception to this was the book of Linn, Helm, and Grabarkiewicz (26) which gives detailed information

telling how custodians may keep a school immaculate. This book tells the type of materials that should be used for each cleaning operation, the proper way to use cleaning tools, the most efficient methods of sweeping floors, washing windows, and of doing the many other cleaning jobs that go to make up the duties of a custodian. In this book the custodian is told not only what should be done in each housecleaning operation of a school, but also why one type of cleaner or preservative is superior to another. One chapter of this book is devoted to the improving of lighting conditions; elsewhere, general and specific responsibilities of custodians, relationship with other school personnel, work scheduling, and fire prevention are discussed in detail. Here, in one source, is a handbook that thoroly covers school housecleaning.

Vacuum cleaners are becoming more widely used in school housekeeping, according to Smalley (37). He predicted that this method of cleaning will displace the broom and stated that St. Louis used vacuum cleaners in all of its school buildings.

School Management (35) was concerned with accidents that befall custodians. It suggested several procedures that would aid in preventing accidents to custodians. Fair (15) listed 35 rules indicating how utility bills might be reduced. Linn (25) listed several factors that should be given attention if high standards of school housekeeping are to be maintained.

School-Plant Maintenance

Maintenance of school buildings has had its fight for funds from the school budget along with other items. The American Association of School Administrators (2) stated that a preferable method for estimating maintenance cost was to base the cost on at least 1 percent of the current replacement cost of the school plant. Hawkins (16, 17) recommended that 1½ and preferably 2 percent of the building's replacement cost be used for maintenance. As building costs rise, maintenance budgets should be increased.

A good maintenance program will keep major repairs to a minimum. The American Association of School Administrators (2) advised as a policy: (a) periodic surveys and inspection to locate needs before emergencies occur, (b) scheduled expenditures for meeting the needs, and (c) well-trained, well-equipped, and experienced maintenance personnel. Hawkins (16, 17) listed five categories under which a good maintenance program falls.

Zepp (45) described a summer maintenance program and stressed the need for sufficient personnel. Zepp (46) also described the school maintenance program in Massillon, Ohio, in which excellent maintenance is secured at relatively low cost. Smalley (36) suggested that floors might be better protected if more attention were given them between the end of the snow slush and the annual summer renovation. Sarver (33) indi-

cated causes of plaster disintegration, described methods of repair, and suggested steps in determining water leaks.

Interior painting of school buildings can serve more purposes than merely to afford a protective covering of the surface. Baker (6) reported that the city of New York, thru research, found color combinations for school interiors that were a positive aid to the education program. Colors were used that would help create a desired environment. Colors with depressing effects were avoided. Safety colors in shops gave silent warnings to students.

Property Insurance

Rising building costs demand reappraisal of school insurance policies if school districts are to be properly insured. Wolverton (44) suggested five methods of determining insurable values. Eichler (14) outlined steps which should be taken in planning an insurance program. He included such elements as: (a) the determination of replacement values, (b) the selection of the most advantageous insurance plan of fire and extended coverage, (c) the use of the staggered or budget plan for premium payments, and (d) the selection of an insurance broker to unite the policies.

A school fire is one of the major tragedies that may happen to a community. Viles (41) described how fire hazards in school buildings could be eliminated, and Benson (9) listed a four-phase program as being a necessity in order that a school have an adequate fire-protection program.

Vandalism in the Chicago schools was reported by Bachrach (5) to have cost the taxpayers over $2 million in a 10-year period. A committee formed to combat the vandalism was successful in greatly reducing the destruction of school property.

Building Rehabilitation

Rehabilitation of school buildings seems a solution to some of the building problems according to the American Association of School Administrators (3). Increased building costs, few changes in statutory limitations on the schoolboards' bonding capacity, and little increase in the assessed valuation of taxable property were cited as prohibiting the adequate construction of new buildings. Moreover, since enrolment peaks may drop after 1965, it was felt to be a matter of good policy to underbuild permanent construction rather than to overbuild. Before any building is rehabilitated, the Association stated, two questions should be explored: (a) are the buildings structurally and educationally worth rehabilitating, and (b) are the buildings, if rehabilitated, needed in the housing of the community's educational program?

Hosler and Swanson (21) described ways of modernizing old buildings. They discussed renovation of heating systems, plumbing, lighting, and other areas. Adams (1) indicated that modern ideas in remodeling school buildings make for better classrooms. Brown (11) presented a floor plan

to show how an old schoolhouse could be remodeled for efficiency and economy. Willis (43) described the modernization and rebuilding of a school that had been partially destroyed by fire.

Starin (38) listed criteria for determining whether a district should remodel or build a new school. Scherer (34) stated that rehabilitating schools should overcome both obsolescence and deferred maintenance.

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CHAPTER VIII

Needed Research in the School-Plant Field

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THE lag is in the construction of school buildings caused by shortages of materials and labor during the past several years has resulted in boosting current estimates for needed school-plant construction to at least $15 billion.

It is imperative that complete data concerning the varied functions of the needed school plant and the costs and efficiencies of materials and processes required to produce the plant be made available to those responsible for planning the school plant. The school plant should provide an environment designed to be used in the development of desirable concepts, skills, attitudes, and behavior in individuals who are living in the school community. It must provide educational facilities for elementary- and secondary-school students including children of kindergarten- and nursery-school ages, and for adults who have the need and desire to improve.

Too many schools have been built without regard to the psychological principles of learning. Consideration should be given to the fact that there is better mastery of basic skills and concepts when they are taught in relation to their use and meaning. Learning is easier and more permanent when students are interested and happy in the content, procedures, and social contacts of the task.

While information concerning many factors has been supplied by previous research and experimentation in the general building field as well as in the school-plant field, there still exists a great necessity for further research if there is to be economy of both time and money in the necessary construction.

A number of excellent suggestions on the need for school-plant research have been reported. Hamon (3), in a previous number of this REVIEW, presented a well-organized recapitulation of earlier lists and added many of the then current subjects. Clapp (2) listed a series of problems in the form of questions and suggested both the collection and organization of previous research studies concerning existing buildings and experimental school buildings. The Commission on American School Buildings of the American Association of School Administrators (1) devoted a chapter of its yearbook to unanswered questions in the school-plant field. Holy and Herrick (4), in the 1950 edition of the *Encyclopedia of Educational Research*, presented a list of basic problems in the location, planning, construction, and operation of school buildings. The National Council on

Schoolhouse Construction (5) presented a guide for planning school plants giving specific recommendations which are educationally acceptable and feasible at this time.

The following enumeration of some of the more specific subjects on school-plant research indicates the main areas in which current fundamental research is needed. This list is not intended to be entirely new, because many of the fields mentioned in previous listings of school-plant research subjects are still in need of further investigation.

Planning

In planning a new school plant there is need for investigations which will provide: (a) implementation of long-term planning to fit the functional requirements of a dynamic educational situation with components such as the expanding role of education, changing to broader curriculums, changing methodology, growing and shifting population and occupational trends, (b) methods of securing active participation on the part of the staff, students, and people in the community so that schools may be planned from the inside out, (c) the apportionment of floor space to different school activities such as instruction, administration, library, physical education, health service, shops, laboratories, classrooms, and auxiliary and community services, (d) greater flexibility and expansibility in structural plan and building materials to permit ready adaptation to the changing personnel, content and methodology of education, (e) accessibility and contiguity of functionally related areas to provide efficient and uncongested student, material, and vehicular traffic, and (f) multiple use of space to approach more closely the full-time use of the different areas of the building and the site.

Finance

Obtaining the greatest value for the taxpayer's dollar necessitates detailed study of the following problems: (a) securing the active support of the tax-paying public, (b) fiscal resources other than local support, with provision for equalization, (c) relation of a pay-as-you-go plan to borrowing by bonding, (d) ascertaining community fiscal capacities thru studies of productive abilities and economic resources, (e) determining suitable legal tax rates, (f) establishing building funds, (g) setting suitable limits for bonded indebtedness, (h) reducing costs of raising money by sale of bonds thru information concerning legal steps, timing, marketing, and retirement, (i) reducing interest costs, (j) developing procedures for strict accounting of monies, (k) cost designing every possible, practical, structural combination for which materials are available, (l) proper timing for the submission of bids, (m) evaluating technics for reducing insurance premiums, and (n) comparing the relative merits of self-insurance with other types of insurance.

Architectural Services

Relatively little significant research concerning architectural services has been reported. There is need for studies leading to knowledge of: (a) architectural, contractual, and administrative procedures, (b) standards of training for the architect, the consulting specialist and the superintendent in connection with school planning, designing, and construction supervision, (c) the relative merits of concentration and division of responsibility, (d) definitions of adequate and proper working plans and specifications, and (e) the development of standard forms of equitable building contracts and bonds, based upon studies of court decisions, state laws, and local regulations.

Codes

There is a tremendous need for the revision of existing codes by the translation of summaries of research results into reasonable accomplishment standards.

Sites

Research is needed to determine areas proper for newer school designs which stress physical education, outdoor education, laboratory training, transportation facilities, and community centers. The following problems in this field need further study: (a) the size, selection, and location of sites suitable to the educational program, (b) availability of sites in more congested areas, and (c) adaptation of building to sites.

Construction

There is need for research on the following problems of school-building construction: (a) determining the most efficient size of building in relation to construction, operation, and maintenance costs, (b) evaluating suitable building materials, taking into account original cost, availability, and utility, (c) securing optimum effectiveness of exterior and interior finishing materials to determine the simplest and most economical combination that will wear well and retain a pleasing appearance, (d) developing designs which are functional, flexible, expansible, and are also pleasing, healthful, and safe, (e) introducing efficient practices with new-type materials and designs, (f) popularizing the use of modular design and prefabrication, including on-site prefabrication, (g) reducing of total labor expense for on-site labor by reducing the skills involved in construction, (h) securing satisfactory acoustics depending upon amount of sound control and types of materials needed for best results in different areas, and (i) modifying the design, color, and trim, of both the interior and exterior of school buildings (including landscaping) according to the way they affect pupils and personnel.

Equipment and Furniture

Good serviceable furniture and equipment is absolutely necessary for optimum child development. There is need for research in this field concerning: (a) efficient, economical planning and installation of instructional and service equipment and furniture, and (b) design, color, performance, specifications, and standards of instructional and service equipment and furniture.

Service Systems

While there has been extensive research concerning service systems, many of the results have been inconclusive and controversial. The main areas for needed research involve the evaluation of: (a) natural and artificial lighting, (b) heating and ventilation, (c) sanitary provisions and facilities, (d) provisions for the convenient and effective utilization of intercommunication, projection, radio, and other audio-visual equipment, and (e) requirements for safe, efficient, and economical transportation including provisions for repair, service, and storage facilities. Of these, the first three need amplification.

Among the controversial or unanswered questions in classroom lighting are: (a) what are the illumination conditions (intensities, brightness ratios, etc.) under which efficient and comfortable seeing for different school activities are made possible, (b) how are these conditions affected by window placement, louvering, external fins, reflection factors, and classroom management, (c) what is the physiological effect of long exposure of natural lighting on the working surface, (d) is automatic photronic control feasible as a solution of light variability, (e) what are the effects of building orientation, room widths, and ceiling heights on lighting, (f) what is the relative illumination thru different types of transparent, translucent, or directional panes and blocks, (g) is natural lighting originating below eye level effective or suitable, (h) what is the effect of different types and colors of window shades and wall finishes on natural lighting, (i) what are the conditions of arrangement and area of windows and translucent areas, (j) what is the effect of size of windows and mullions on natural lighting and visibility in the classroom, (k) what is the effect of placement of equipment on classroom lighting, (l) is unilateral lighting suitable for classrooms where tables and chairs are used, and (m) is multilateral lighting suitable for the colder climates?

In the field of heating and ventilation the following are some of the unanswered questions: (a) Is window-gravity-ventilation feasible and satisfactory in all climates and seasons? (b) If mechanical systems of heating and ventilating are used, what are the optimum volumes of air per pupil, numbers of air changes, and proportions of fresh and recirculated air? (c) What are the optimum temperature and humidity conditions for health and alertness in the different school activities? (d) Can air conditioning be provided successfully and economically under typical

school conditions? (e) What ventilation problems arise because of differences in building design and material? (f) What economies can be effected by separate heating circuits for areas used only part-time? (g) To what extent, and by what means is air sterilization desirable and feasible? (h) In radiant heating, what are optimum panel areas, locations, and temperature? (i) What controls may be used to compensate for heating and cooling lags in radiant heating?

Unanswered questions concerning sanitary systems include the following: (a) What are the special requirements of ventilation in toilets and locker rooms? (b) To what extent and under what conditions are germicidal lights and aerosols effective? (c) What are the toilet requirements for different pupil-age levels and types of activities? (d) What are the requirements for drinking, bathing, and washing facilities in the whole school program?

Maintenance and Operation

In the field of maintenance and operation, the principal questions on which further research is needed are: (a) What are the maintenance and operation costs of schools in relation to such factors as size of building, types of construction, uses and climate? (b) What is the proper care of new-type materials in different climates? (c) Under what conditions should a building be repaired, remodeled, or replaced?

Need for Coordinated Research

It is not enough merely to undertake the isolated investigation of these important problems of the building program. The results of the researches must be made available and understandable to those who are actively engaged in the planning and construction of schools. That is, the voluminous information in completed research studies must be collected, evaluated, condensed, summarized, interpreted, and distributed to those who need it. There is a need for a cooperative attack on this important research area in a comprehensive and scientific manner.

It is believed that this problem can be handled most effectively by encouraging administrative officers to help in securing funds, in answering questionnaires, in rendering other requested services to the existing research centers including city schools, state departments of education, universities, and such national organizations as (a) The National Council on Schoolhouse Construction, (b) The National Education Association, (c) The American Council on Education, (d) The American Institute of Architects, and (e) The United States Office of Education. To provide the necessary personnel for work on school-plant problems in the research centers, American colleges must train more students in the school-plant field.

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